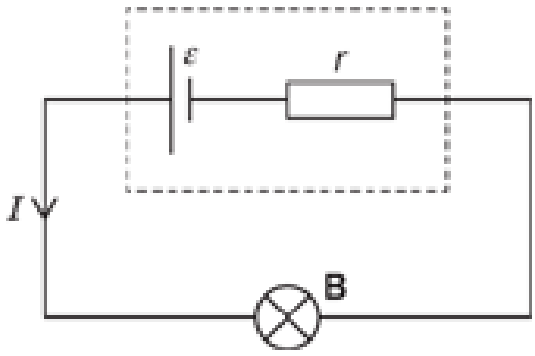
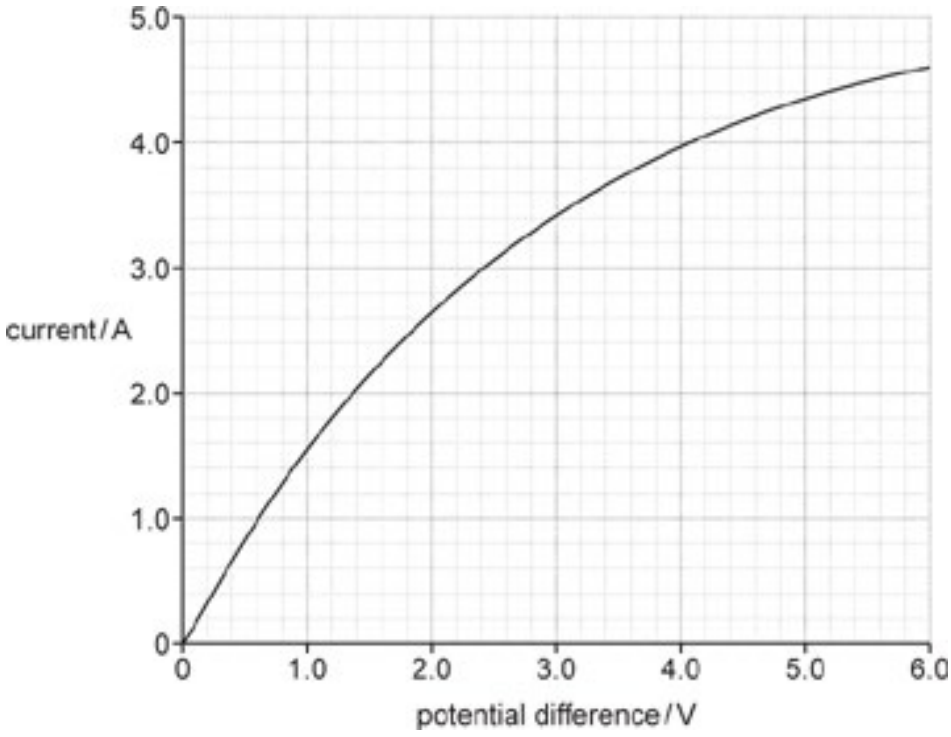
1. A cell has internal resistance r = 1.2 Ω and e.m.f. ε = 5.6 V.

When the cell is connected to a filament lamp **B**, as shown in the circuit diagram below, the current in the circuit is I.



The I-V characteristic for **B** is shown in the figure below.



Determine the current I in the circuit.

current = ... A **[3]**

2. A thermistor has a resistance that decreases as temperature increases.

A student makes measurements to plot the variation of resistance with temperature of the thermistor.

They submerge the thermistor into distilled water at 50˚ C.

They then record measurements from a voltmeter and ammeter as the temperature of the water falls to about 20˚ C.

Describe how the student obtains sufficient data to plot a graph of resistance against temperature.

Your answer should include a circuit diagram.

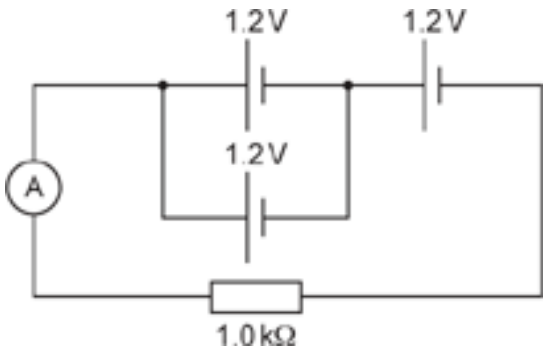
[4]

3. Which is an S.I. base unit?

A amp
B coulomb
C ohm
D volt

Your answer ☐ **[1]**

4. A 1.0 kΩ resistor is connected in series to a battery made of three 1.2 V cells connected as shown. The cells have negligible internal resistance.



What is the reading on the ammeter?

A 1.2 mA
B 1.8 mA
C 2.4 mA
D 3.6 mA

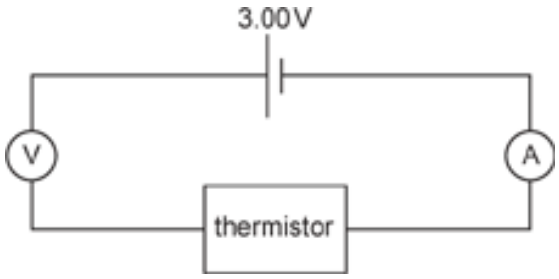
Your answer ☐ **[1]**

5(a). Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



Describe how the student should change the circuit.

---

[1]

(b). The circuit was corrected and then used to collect data.

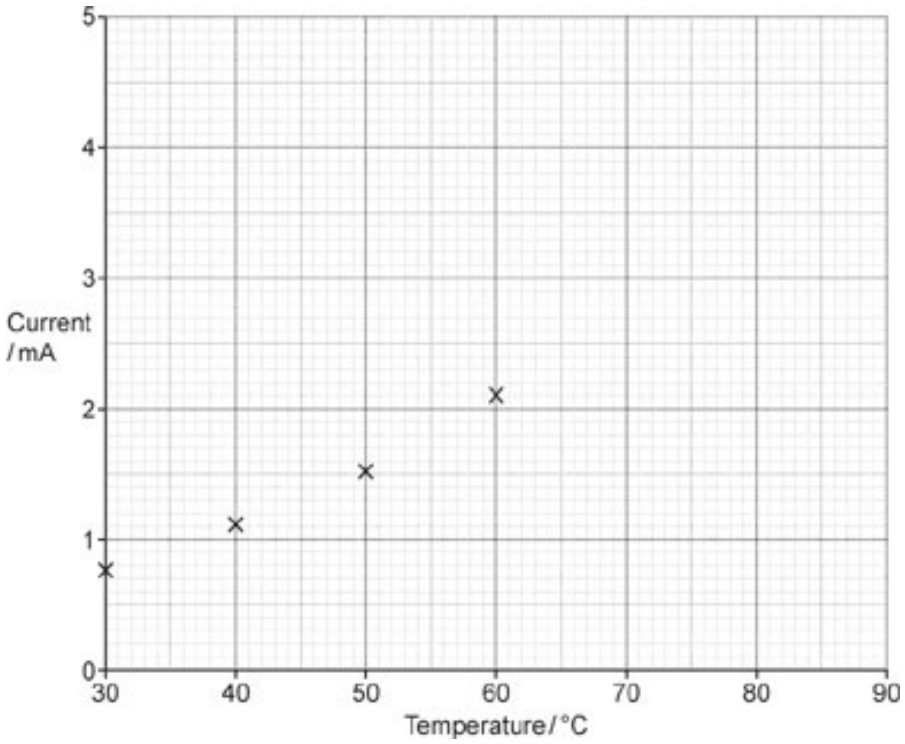
The table shows data collected from the investigation.

Temperature/°C	Current/mA	Voltage/V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

i. The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

ii. Draw a suitable line of best fit through the data points.



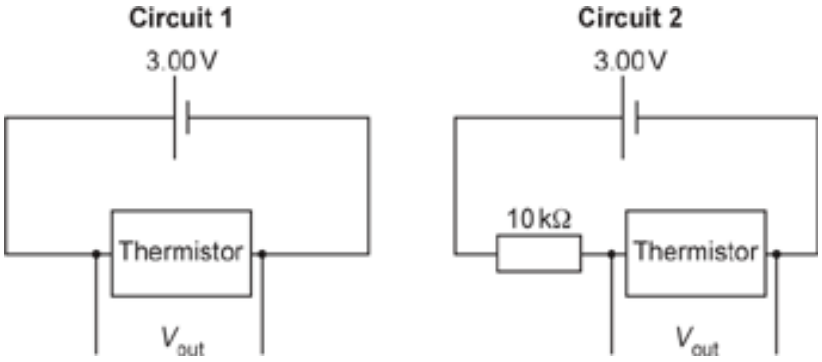
[1]

(c). Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

[3]

(d). The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.

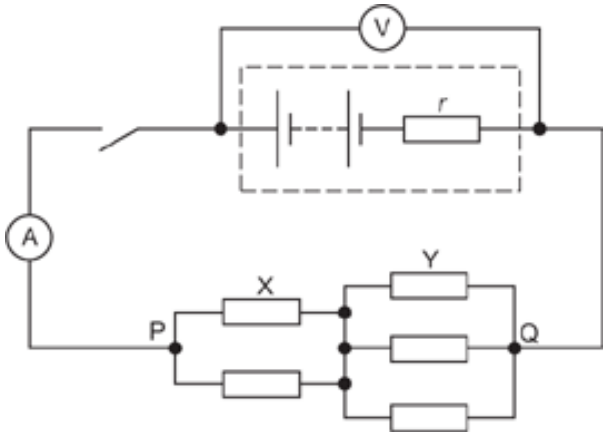


In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

[4]

6(a). A battery of electromotive force (e.m.f.) ε and internal resistance r is connected to five identical wire wound resistors in a circuit.



Each resistor between points P and Q has a resistance of 300Ω. Two of the resistors are labelled X and Y as shown.

The table shows the ammeter and voltmeter readings when the switch is open and when the switch is closed.

Switch position	Ammeter reading	Voltmeter reading
open	0.0 mA	4.57 V
closed	18.0 mA	4.50 V

i. Suggest why a student deduces that the e.m.f. ε of the battery has the value of 4.57 V.

[1]

ii. Show that the resistance r is approximately 3.9 Ω.

[1]

iii. Show that the total resistance of the resistors between P and Q is 250 Ω.

[1]

(b). The switch is closed for 300 s.

Calculate:

i. the energy *E* dissipated in *r*.

E = ... J **[1]**

ii. the number of electrons *N* passing through *r*.

N = ... **[2]**

iii. the ratio

$$\frac{\text{mean drift speed of electrons in resistor X}}{\text{mean drift speed of electrons in resistor Y}}$$

ratio = ... **[2]**

(c). Resistor Y is removed from the circuit.

The switch is closed.

Complete the sentences to state the change, if any, in the meter readings.

Choose from **increases, decreases,** or **stays the same**.

i. The ammeter reading

_____ **[1]**

ii. The voltmeter reading

_____ **[1]**

7(a). A switch, resistor of resistance *R* and a component **Z** are connected to a battery of electromotive force (e.m.f.) *E* and internal resistance *r*. An ammeter and voltmeter are also connected to the circuit as shown in **Fig. 6.1**.

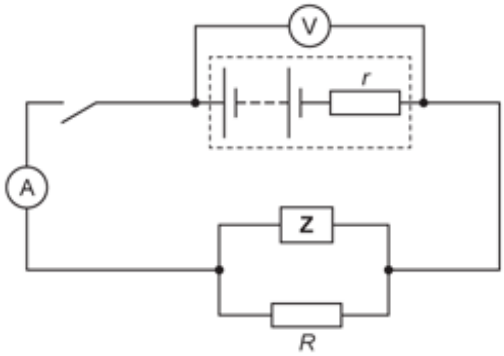


Fig. 6.1

Fig. 6.2 shows the current *I* and potential difference *V* characteristic for the electrical component **Z**.

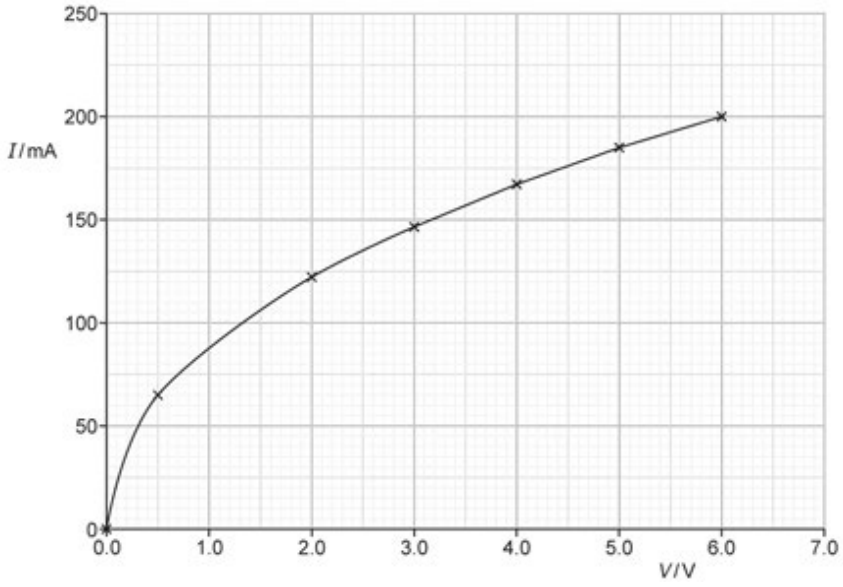


Fig. 6.2

State the name of component **Z**.

_____ **[1]**

(b). The switch is initially open.

The voltmeter reading is 5.72 V

The following voltmeters are available:

A: 0–2 V, ± 0.001 V	**B:** 0–2 V, ± 0.01 V	**C:** 0–2 V, ± 0.1 V
D: 0–20 V, ± 0.001 V	**E:** 0–20 V, ± 0.01 V	**F:** 0–20 V, ± 0.1 V

State the voltmeter, **A** to **F**, that has been used in this experiment.

Voltmeter ..... **[1]**

(c). The switch is now closed.
The ammeter and voltmeter readings are:
Ammeter reading = 220 mA
Voltmeter reading = 4.80 V

i. Show that the resistance of *R* is 120 Ω.

[2]

ii. Determine values for *E* and *r*.

E = ... V

r = ... Ω

[3]

(d). The resistor *R* is changed to a lower value.

State and explain the change, if any, in the ammeter and voltmeter readings when the switch is closed.

[4]

8.

The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

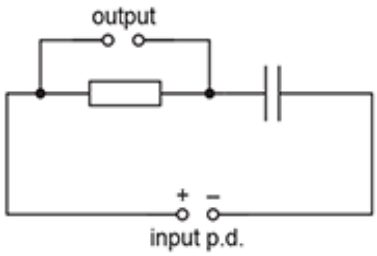


Fig. 6.1

i. **Fig. 6.2** shows the input signal of potential difference (p.d.) *V* against time *t*.

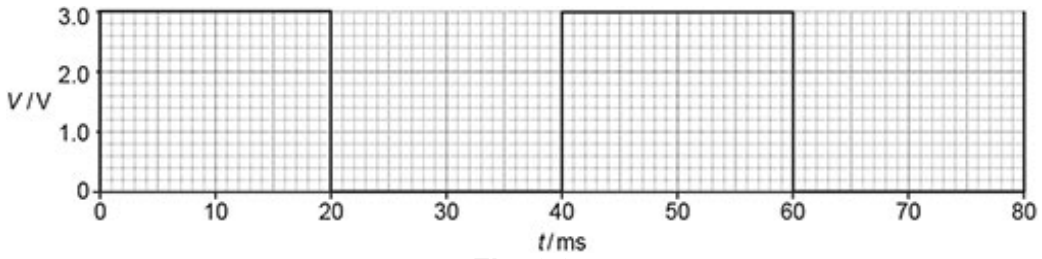


Fig. 6.2

Calculate the frequency *f* of this input signal.

f = ... Hz **[2]**

ii. **Fig. 6.3** shows the variation of the charge Q on the positive plate of the capacitor with time t.

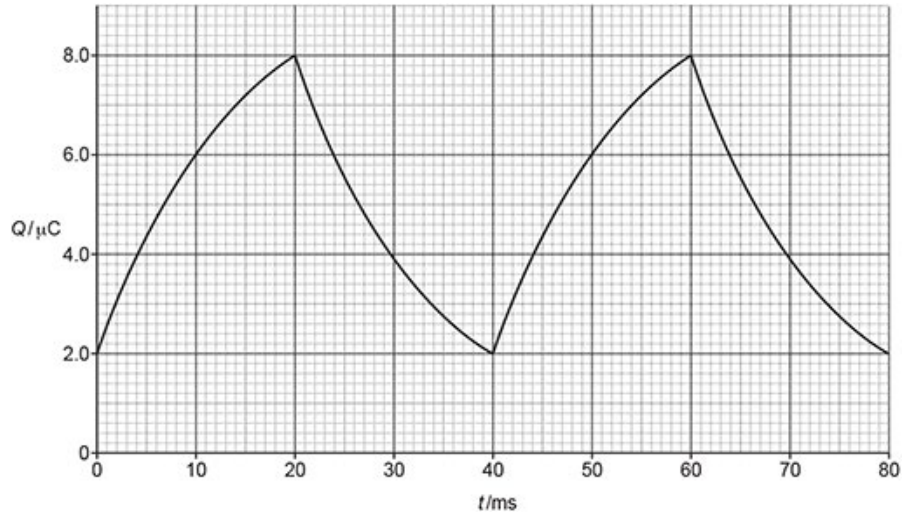


Fig. 6.3

Use a discharging section of the graph in **Fig. 6.3** to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms **[2]**

iii. By drawing a suitable tangent to the graph in **Fig. 6.3**, calculate the maximum current in the resistor.

maximum current = ...A **[2]**

iv. On **Fig. 6.4** below, sketch the variation of the current I in the resistor with time t. Include an appropriate label and scale on the vertical axis.

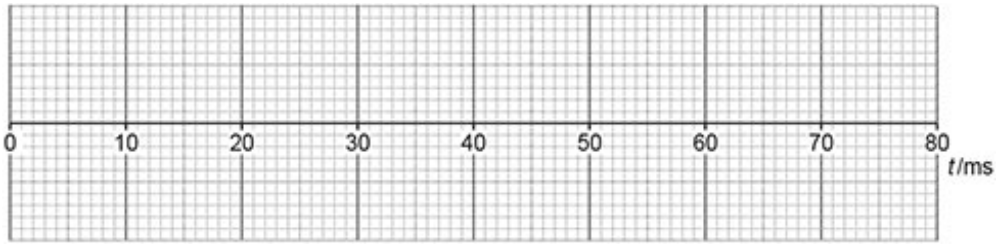


Fig. 6.4

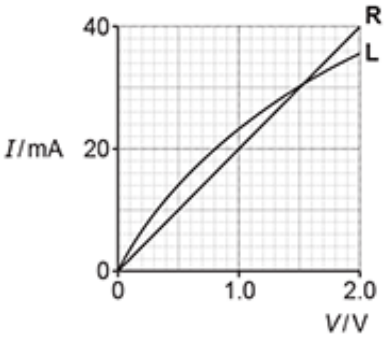
[3]

9. A wire in a circuit obeys Ohm's law.
Which statement about the wire is linked to this law?

A The current in the wire is directly proportional to the potential difference across it.
B The current in the wire is inversely proportional to its resistance.
C The resistance of the wire is directly proportional to its length.
D The resistance of the wire is inversely proportional to its cross-sectional area.

Your answer ☐ **[1]**

10. The *I*-*V* characteristics of two components **R** and **L** are shown below.



Which statement is correct?

A **R** and **L** are both filament lamps.
B **R** and **L** have the same resistance at 1.5 V.
C The resistance of **L** is independent of potential difference *V*.
D The resistance of **R** increases as the potential difference *V* increases.

Your answer ☐ **[1]**

11(a). An electric cooker has two independent heating rings **A** and **B** as shown in **Fig. 7.1**.

Fig. 7.1

The cooker rings **A** and **B** are connected in parallel to a 230 V power supply. At maximum power, ring **A** has a power of 1100 W and ring **B** has a power of 1700 W.

The filament in ring **A** is a metallic wire of length 11.8 m.
At maximum power the wire has resistance 31 Ω and the metal has resistivity 4.8×10^{-7} Ω m.

Calculate the diameter *d* of the wire.

d = ... m **[3]**

(b). Fig. 7.2 shows the circuit symbol for ring **A**.

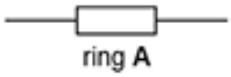


Fig. 7.2

A student uses a battery of four cells, an ammeter and a voltmeter to determine the resistance of the wire in ring **A** experimentally.

i. Complete **Fig. 7.2** to show how the student should connect the circuit to determine the resistance.

[2]

ii. The current in the wire is 0.34 ± 0.02 A and the potential difference across the wire is 6.2 ± 0.2 V.

Calculate the resistance *R* of the wire.

R = ... Ω **[1]**

iii. Calculate the percentage uncertainty in *R*.

percentage uncertainty = ... % **[2]**

iv. Suggest why *R* from **(c)(ii)** is less than 31 Ω.

_____

_____

_____

[2]

v. Suggest **two** improvements to the student's experiment to determine *R* experimentally.

1 _____

_____

_____

2 _____

_____

_____

[2]

END OF QUESTION PAPER